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by

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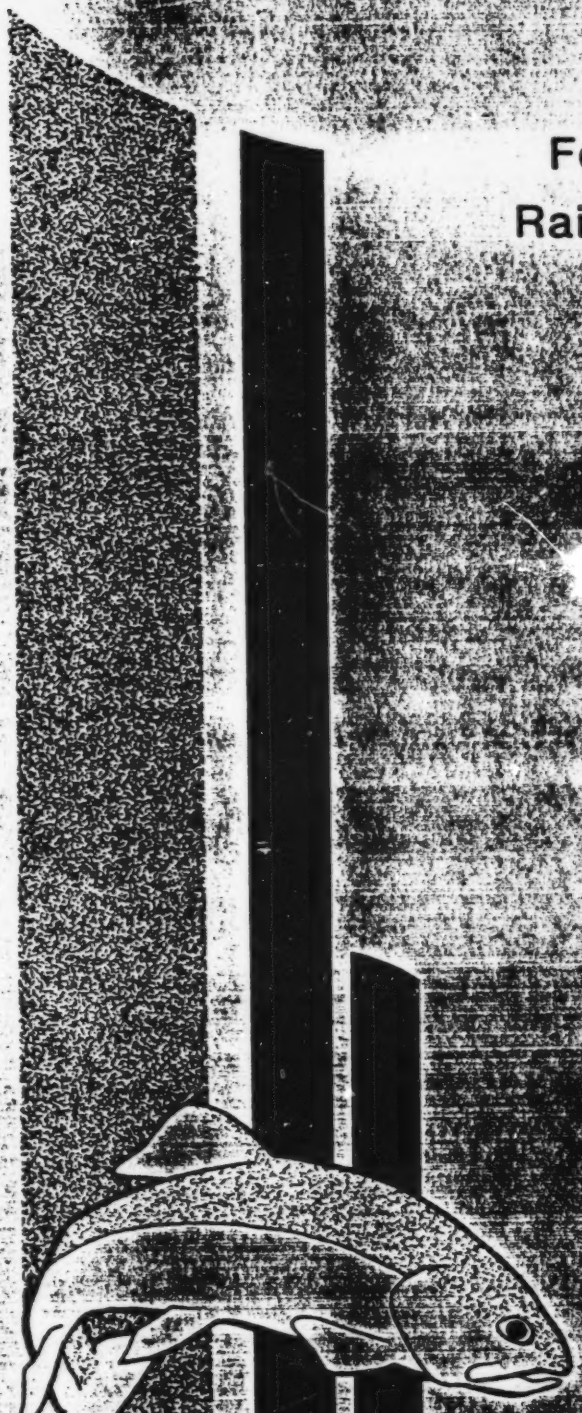

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FOOD HABITS OF GERRARD STOCK RAINBOW TROUT IN KOOTENAY LAKE, BRITISH COLUMBIA

by

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ABSTRACT

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Kokanee and terrestrial insects were found to be the main food items of the Gerrard stock of rainbow trout. Mysis were not a major food item. Conspicuously absent were other typical rainbow food items such as benthic invertebrates and zooplankton. Kokanee as a diet item increased in importance in the winter and with increasing rainbow size. The construction of the Duncan Dam, which destroyed a major kokanee spawning area, had no noticeable effect on the diet of these fish.

INTRODUCTION

Over the years fisheries workers in the Pacific Northwest have expressed a great deal of interest in the biology of Gerrard stock rainbow trout which inhabit Kootenay Lake. Cartwright (1961) initially described their racially distinct features which separate them from other stocks in Kootenay Lake. Hartman (1969) has studied their reproductive biology in considerable detail. Northcote (1973) reviewed their recent history relative to sport fishing, size and growth. Irvine (1978) provided an excellent account of their early life history and spawning population estimates at the only known spawning site--Gerrard. The contribution of this stock to the sport fishery was reported by Andrusak (1981).

Throughout the course of the last two decades of fisheries work on Kootenay Lake, rainbow trout stomach samples have been collected as part of or ancillary to specific research projects.

The following report is an attempt at collating food habits of Gerrard rainbow trout recognizing the considerable variation when data was collected each year, what food items were analyzed and what method of measurement was used. Despite certain anomalies in the data, a good deal of comparable information is available. While the majority of trout are undoubtedly Gerrard stock, it should be noted that some other trout may be included in the analysis.

STUDY AREA

Kootenay Lake is a large oligotrophic lake approximately 105 km long and 3 km wide. It has three arms--north, south and west (Fig. 1) with the west arm being the outlet for the main body of the lake. A more detailed description of the lake's limnology can be found in Cloern (1976).

METHODS

Stomach samples were taken only from sport caught rainbow trout and were usually obtained from a collection station at the Kaslo marina. Usually, the length and weight of fish were recorded and the whole stomach was then preserved in formalin for later analysis. Fish less than 15 cm were not sampled since this size is not available to the fishery.

Stomach contents were analyzed usually by volume displacement and/or percent occurrence. The volume displacement method involved measuring the total volume of food material by water displacement to the nearest 0.5 ml. After measuring total volume, major components were then recorded separately. Food

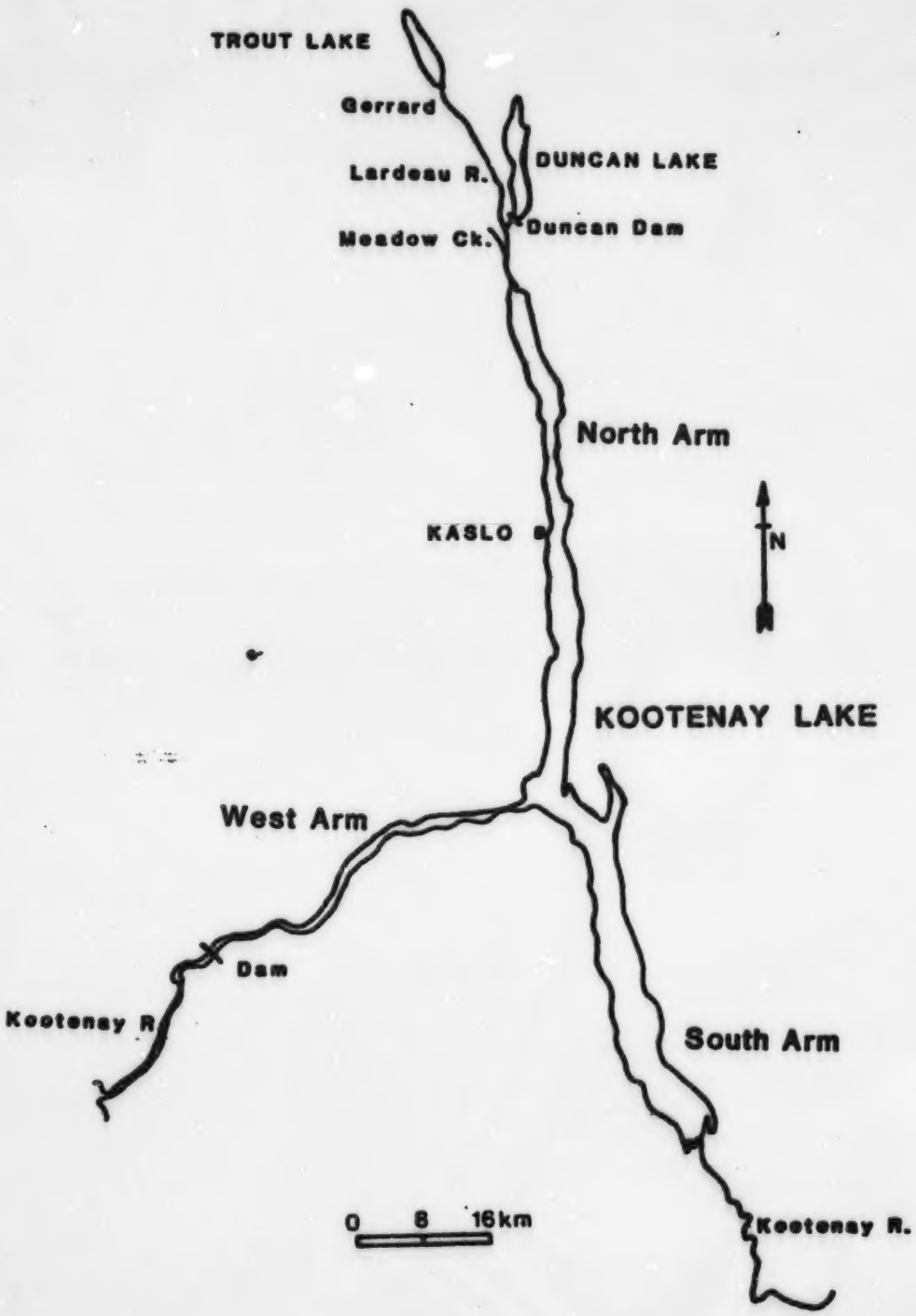

Fig. 1. Map of study area.

volumes of each category were totalled for the month and expressed as a percentage of total consumed for the month. Percent occurrence figures indicate the percent of stomach which contained each food item calculated monthly. Several years of data analysis also included the number of kokanee found per rainbow trout stomach.

Method of analysis for 1928-29 and 1949 data cannot be determined. That is, it is unclear whether all stomachs, including empty ones, were included in percent volume calculations or whether just stomachs with food were used. All data from 1964-80 involved analysis of only those stomachs which contained food.

For comparative purposes all rainbow trout for all years have been grouped into three size categories: fish less than 30 cm, fish between 31-45 cm and all fish greater than 45 cm.

Separation of food types varied considerably from one project to the next. Therefore, for comparisons between years, food categories have been reduced to two groups: all insects and plankton as one group and all fish as the other.

RESULTS

FOOD ITEMS

Data collected in 1973 are used to illustrate typical food habits of north arm rainbow trout. In 1973 an estimated 1150 rainbow trout were caught in the fishery. Of those 1150, some 258 were analyzed for food habits. Fish samples were taken each month of the year, the fish ranged in size from 17-93 cm and were 1-8 years of age. Table I represents food habits of the fish sampled in 1973. Table 2 represents the same data expressed as percent occurrence.

The majority of insects found in the rainbow stomachs were terrestrial forms. Hymenopterans (flying ants) and various terrestrial form beetles (Coleoptera) were quite abundant, particularly in the spring months. A few aquatic dwelling insects were present but they represented less than 1% of the total insect volume. Insects were an important, dominant food item for small trout but were of secondary importance to fish greater than 50 cm.

Zooplankton were found in some rainbow trout, particularly those less than 30 cm, but plankton contributed very little to the diet of even the smallest rainbow (Table 1). When plankton was present, it was represented exclusively by <u>Mysis relicta</u>.

Kokanee are the primary food item for these rainbow trout

(Tables 1 and 2), making up over half of the volume of the stomach contents of all but the smallest size class. Terrestrial insects are more important to trout under 30 cm but kokanee still represent over 1/3 of the diet by volume.

Kokanee are essentially the only fish species eaten even though a number of other potential prey species are present in the lake. In the 1973 data only one other fish, a redsided shiner (Richardsonius balteatus), was observed in any of the rainbow trout stomachs. Actual measurements of kokanee found in the rainbow stomachs were not made but the majority of them were 12-16 cm in length. In some of the large trout (>50 cm) 2-6 kokanee per stomach were common.

Seasonal Variation in Food Habits

The major seasonal change in food habits is an increased dependence on kokanee during the winter months (October to March). This shift is most apparent in the percent volume data for trout >45 cm (Table 3) but also occurs in smaller fish and in the percent occurrence data (Table 4). Sample sizes for small fish in the winter are low because the winter sports fishery is highly selective for large fish.

Insects in the diet are mostly terrestrial forms which are not active during the winter months and it is therefore not surprising that they are less prevalent in the diet at this time. Trout of all sizes feed heavily on large concentrations of certain insects which occur at specific times of the year, particularly flying ants in June. It should be emphasized that insects are an important part of the summer diet of even the largest fish where they make up about one-third of the volume of the stomach contents. The winter diet of trout <30 cm continues to be mainly plankton and insects but these are primarily Mysis and a few aquatic insects.

Variation in Diet between Years

Construction of the Duncan dam (completed in 1967) resulted in a substantial loss of kokanee production (Peterson and Withler 1965). The Meadow Creek kokanee spawning channel began operating in 1967 in an attempt to compensate for kokanee losses resultant from the Duncan dam. The prime purpose of Meadow Creek kokanee production is to provide forage for Kootenay Lake rainbow trout and Dolly Varden. It is therefore of interest to compare food habits of trout before and after construction of the Duncan dam. Only summer stomach samples were available both before and after dam construction. Percentage occurrence of kokanee in the diet is similar during the two periods (Table 5). Percent volume data is not as consistent with a notable decrease in the importance of kokanee in 1964 (Table 6). There is, however, no indication of a general decline in the importance of kokanee following the completion of the Duncan dam.

Table 1. Food habits of rainbow trout from the north arm of Kootenay Lake, 1973. Expressed as average percent volume.

Size Group	Sample Size	Food Items		
		Kokanee (%)	Insects (%)	Zooplankton (Mysis) (%)
17-29.9	28	35	61	4
31-39.9	46	56	42	2.9
40-49.9	36	71	29	0.3
50-59.9	53	87	13	0.3
60-69.9	37	90	10	0.2
70-79.9	34	93	7	-
80	24	71	29	-

N = 258

Table 2. Percent occurrence of food types in north arm rainbow trout, 1973 (empty stomachs excluded).

Size Group (cm)	Sample Size	Food Items		
		Kokanee (%)	Insects (%)	Zooplankton (Mysis) (%)
17-29.9	28	11	96	25
30-39.9	38	24	82	13
40-49.9	35	34	71	11
50-59.9	38	66	39	13
60-69.9	25	72	36	4
70-79.9	16	81	25	-
>80	14	86	21	-

Table 3. Average percent volume of food items in rainbow trout spring-summer and fall-winter.

	Size Group <30 cm		30-45 cm		>45 cm	
	Kokanee (%)	Plankton & Insects (%)	Kokanee (%)	Plankton & Insects (%)	Kokanee (%)	Plankton & Insects (%)
1969,70,73 Summer	9 (160)	91	47 (200)	53	67 (164)	33
Summer 1980	- -	-	17 (3)	83	65 (35)	35
1969,72,73 Winter	0 (9)	100	82 (10)	18	99 (66)	1
Winter 1980	- -	-	- -	-	99 (38)	1

Table 4. Percent occurrence of food items in north arm Kootenay Lake rainbow trout spring-summer* and fall-winter (excluding empty stomachs). Sample sizes are in brackets.

	Size Group <30 cm		30-45 cm		>45 cm	
	Kokanee (%)	Plankton & Insects (%)	Kokanee (%)	Plankton & Insects (%)	Kokanee (%)	Plankton & Insects (%)
*Summer 1966-73	7.4 (163)	95	27 (256)	80	28 (268)	52
Summer 1980	- -	-	33 (3)	100	68 (35)	45
*Winter 1966-73	11 (9)	89	41 (17)	59	73 (146)	27
Winter 1980	- -	-	- -	-	97 (38)	3

*Spring/summer - April/September
Fall/winter - October/March

Table 5. Percent occurrence of food in north arm rainbow trout--summer diet (April 1 - September 30).

	Length Frequency					
	<30 cm		30-45 cm		>45 cm	
Year	Kokanee (%)	Plankton & Insects (%)	Kokanee (%)	Plankton & Insects (%)	Kokanee (%)	Plankton & Insects (%)
1949	5 (107)	93	21 (26)	74	33 (44)	42
1964	- (83)	95	8 (186)	79	40 (218)	60
1966 & 1967	11 (37)	89	24 (59)	76	39 (184)	61
1968-74	6 (130)	93	25 (221)	75	41 (236)	59
1980	- -	-	17 (3)	83	65 (35)	35

Table 6. Summer diet (April 1 - September 30) of Kootenay Lake rainbow trout (north arm) in average percent volume.

	<30 cm		30-45 cm		>45 cm	
Year	Kokanee (%)	Plankton & Insects (%)	Kokanee (%)	Plankton & Insects (%)	Kokanee (%)	Plankton & Insects (%)
1949	30 (107)	70	27 (26)	73	78 (44)	12
1964	- (83)	95	10 (186)	85	34 (218)	63
1969, 1970, 1973	9 (160)	91	47 (200)	53	67 (164)	33
1980	- -	-	17 (3)	83	65 (35)	35

Age Characteristics

One of the outstanding features of Gerrard stock rainbow trout is the old age at which they mature. Cartwright (1961) found that 90% first spawn at 5 or 6 years old and a few repeat spawn thereafter. Age analysis of 1973 sport caught rainbow (from Kaslo area) conforms closely to that determined by Cartwright (1961).

Table 7 illustrates a length-age relationship. The majority of fish aged by scale analysis were taken from June-November 1973, therefore a plus (+) is indicated as summer growth, i.e. 1973 summer growth.

Table 7. Length-age relationship for rainbow trout from the north arm of Kootenay Lake, 1973.

Age	Mean Length (cm)	Range (cm)	Sample
1+	22.6	17-29	5
2+	31.5	19-47	39
3+	45.6	28-63	40
4+	59.8	41-84	36
5+	70.1	43-93	28
6+	74.3	55-89	9
7+	72.0	68-76	2

The large increase in growth from a 2+ to a 3+ and again from a 3+ to 4+ coincides with stomach analysis data which indicates increased utilization of kokanee. Apparently, Gerrard stock rainbow trout are heavily utilizing kokanee by the time they attain 3 years of age.

DISCUSSION

An extensive literature exists on the feeding habits of rainbow trout and related species in lakes (Carlander 1969). More recent work has confirmed the general conclusions of earlier authors. The diet of rainbow is extremely diverse but food items fall into four main categories; zooplankton, benthic invertebrates, terrestrial insects and fish. Daphnia are usually the only zooplankton prey with larger individuals (>1.3 mm) strongly preferred (Taylor and Gerking 1980, Galbraith 1967). Benthic invertebrates include a wide variety of organisms such as amphipods, aquatic insects, molluscs and leeches. Terrestrial insects usually form a small part of the diet but again include a wide variety of species. When other fish species are present, piscivory is only common in larger individuals which shift to a fish diet between about 25 and 40 cm (Crossman and Larkin 1959, Marrin and Erman 1982, Jeppson and Platts 1959, Stocek and McCrimmon 1965). The unusual features of the diet of Kootenay rainbow are a dependence on terrestrial insects and a corresponding lack of benthic invertebrates and zooplankton in small fish and the absence of fish species other than kokanee in larger individuals.

Terrestrial insects are a minor food item for rainbow in many lakes (e.g. Nilsson and Northcote 1981, Marrin and Erman 1982), but only in a few instances are they the dominant food item (e.g. Wales 1946). Terrestrial insects are, however, the dominant food item of westslope cutthroat trout in a number of large lakes and reservoirs in Idaho and Montana (Bjornn 1957, McMullin 1979, Leathe and Graham 1982). In most other lakes terrestrial insects are not the dominant food of cutthroat trout (Carlander 1969). Cutthroat trout in these lakes have a similar life history to that of Kootenay Lake rainbow (described by Irvine 1978) in that they rear in streams for some time before migrating to a lake. The difference seems to be that these cutthroat do not switch to a fish diet and therefore do not attain the large size seen in Kootenay Lake rainbow.

There is no conclusive explanation for the importance of terrestrial insects in the diet of these trout but it may be related to the presence of competitor fish species. Competitor species can cause a dramatic decrease in the importance of benthic invertebrates in the diet of rainbow (Johannes and Larkin 1961). The may also reduce the ability of rainbow to utilize zooplankton. Most studies show that rainbow feeding on zooplankton only utilize large Daphnia. A number of authors (summarized by Zaret 1980) have shown that large Daphnia are very susceptible to fish predation and are often completely removed from the zooplankton community following the introduction of a variety of planktivorous fish. In Kootenay Lake, the dominant planktivore is the kokanee (Oncorhynchus nerka) which is capable of feeding on a variety of zooplankton down to a size of about .4 mm and which shows a marked preference for Daphnia (Rieman and Bowler 1980). Mysis relicta, which were introduced to Kootenay

Lake have also been implicated as serious zooplankton predators which may be capable of eliminating cladoceran populations (Morgan et al. 1978). Daphnia densities in Kootenay Lake have decreased dramatically in recent years (Zyblut 1970, Cloern 1976). A dependence on terrestrial insects may therefore be a strategy developed in response to competition.

The absence of benthic invertebrates in the diet of Kootenay Lake rainbow may also be due to water level fluctuation which can reduce benthic invertebrate populations (Grimas 1962, Hynes 1961) and force fish to alter their diets. Kootenay Lake is used as a hydroelectric reservoir with a maximum drawdown of 2.4 m (Northcote 1973). Many of the large Idaho and Montana lakes in which westslope cutthroat depend on terrestrial insects are also reservoirs.

The reason that kokanee are the main fish species in the diet of Kootenay Lake rainbow is probably because kokanee are the dominant pelagic planktivore in the lake. The major food item of large salmon and trout in large lakes is often the dominant planktivore. In Lake Michigan, the alewife and rainbow smelt, the dominant planktivores, are the major food items of coho salmon, chinook salmon and brown trout (Stewart et al. 1981). Brown trout feed on sculpins to some extent but other benthic and littoral species are almost absent from the diet of these salmonids. In Pyramid Lake, piscivorous cutthroat fed almost exclusively on tui chub, the dominant pelagic species (Sigler et al. 1983). No sampling of prey populations was done in Kootenay Lake but kokanee are the dominant pelagic fish species in nearby Pend Oreille Lake (Rieman and Bowler 1980) and Skaha Lake (data on file), both of which have a fish fauna similar to that of Kootenay Lake.

Using only this data there is some difficulty in establishing the importance of kokanee in the energy budget of these rainbow trout. Anglers often fish using lures imitating kokanee which may bias our sample toward individual trout which are feeding on kokanee. Percent volume data cannot be used to directly infer the relative importance of different diet items in terms of energy intake because of different digestion rates. Indirect evidence for the importance of forage fish is the increase in growth rate which coincides with increasing utilization of kokanee. A similar pattern of an increased growth rate coinciding with the onset of piscivory occurs in the other large salmonids (lake trout, Martin 1970; cutthroat trout, Sigler et al. 1983).

This study suggests that a healthy kokanee population is essential to the existence of Kootenay Lake rainbow. Possible threats to kokanee include destruction of spawning habitat, introduction of competitors, overfishing and an increase in the predator population. All of these factors are present on Kootenay Lake. Logging activities and hydroelectric dams have destroyed spawning areas. Mysis relicta, introduced as food, may

in fact be a serious competitor (Morgan et al. 1978). Kokanee catches in the west arm have declined from a peak of 112,000 to a low of 3600 due to overfishing, but catches in south and north arms continue to increase slowly (Andrusak 1981).

Perhaps the least obvious threat to the kokanee population is the rainbow themselves. Data on Lake Michigan lake trout indicates that gross conversion efficiency in terms of weight averages 12.2% (Stewart et al. 1983). If we assume that the conversion efficiency for a large rainbow is similar and that the diet is 50% kokanee then each 5 kg rainbow has consumed approximately 20 kg of kokanee in its lifetime. Since average size of kokanee eaten was approximately 15 cm (~50 g), a total of 400 could be eaten in a lifetime. Enhancement of piscivorous populations of rainbow should not take place without a preliminary analysis similar to that of Stewart et al. (1983) to determine if prey populations are capable of supporting the increase in the numbers of predators. During the enhancement program that is currently underway for Gerrard trout on Kootenay Lake, their food habits and growth rate will be monitored along with kokanee population trends.

Our data indicates that mysis introductions are not useful as a means of increasing the rainbow trout forage base in a large lake like Kootenay Lake. Mysis were introduced to Kootenay Lake to provide forage for rainbow, Dolly Varden and kokanee. In the shallow west arm of Kootenay Lake kokanee and rainbow utilize Mysis heavily but they are not an important diet item for rainbow, Dolly Varden or kokanee in the north and south arms of the lake (Northcote 1973). In other large lakes, salmon and trout species, other than lake trout, do not consistently include a significant number of mysis in their diet (Gosho 1975, Ellis and Bowler 1981, Morgan et al. 1978, Stewart et al. 1981).

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